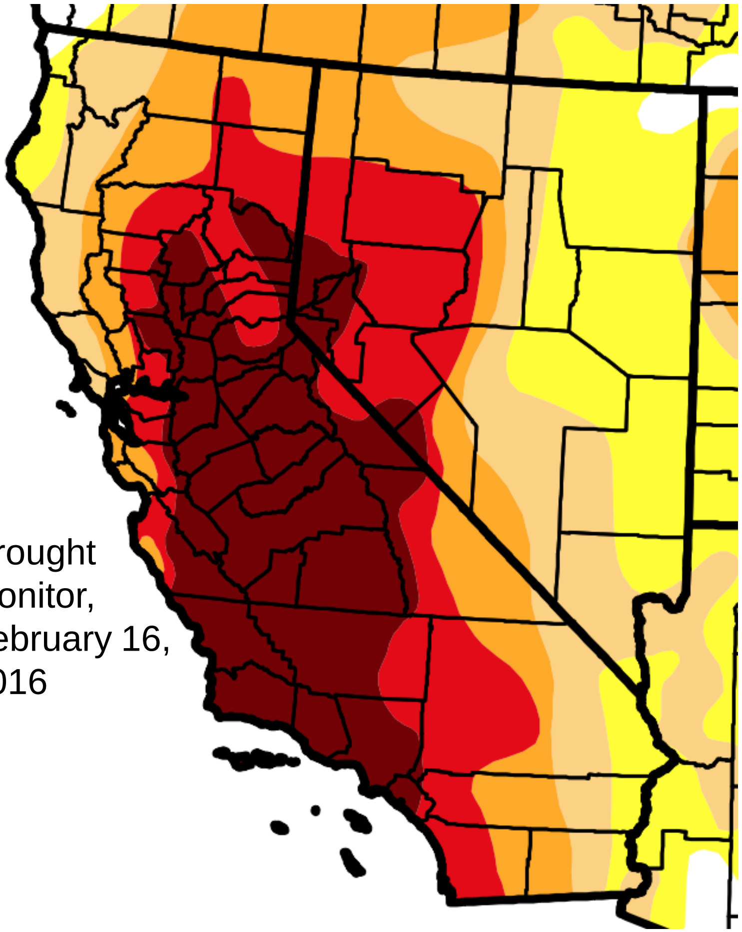
Drought University: *Seniors*

February 24, 2016
RISA Annual Meeting



Drought Monitor, February 16, 2016

California-Nevada Climate Applications Program
A NOAA RISA team

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

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3 Lessons Learned

from the 2012-2015 CA/NV drought

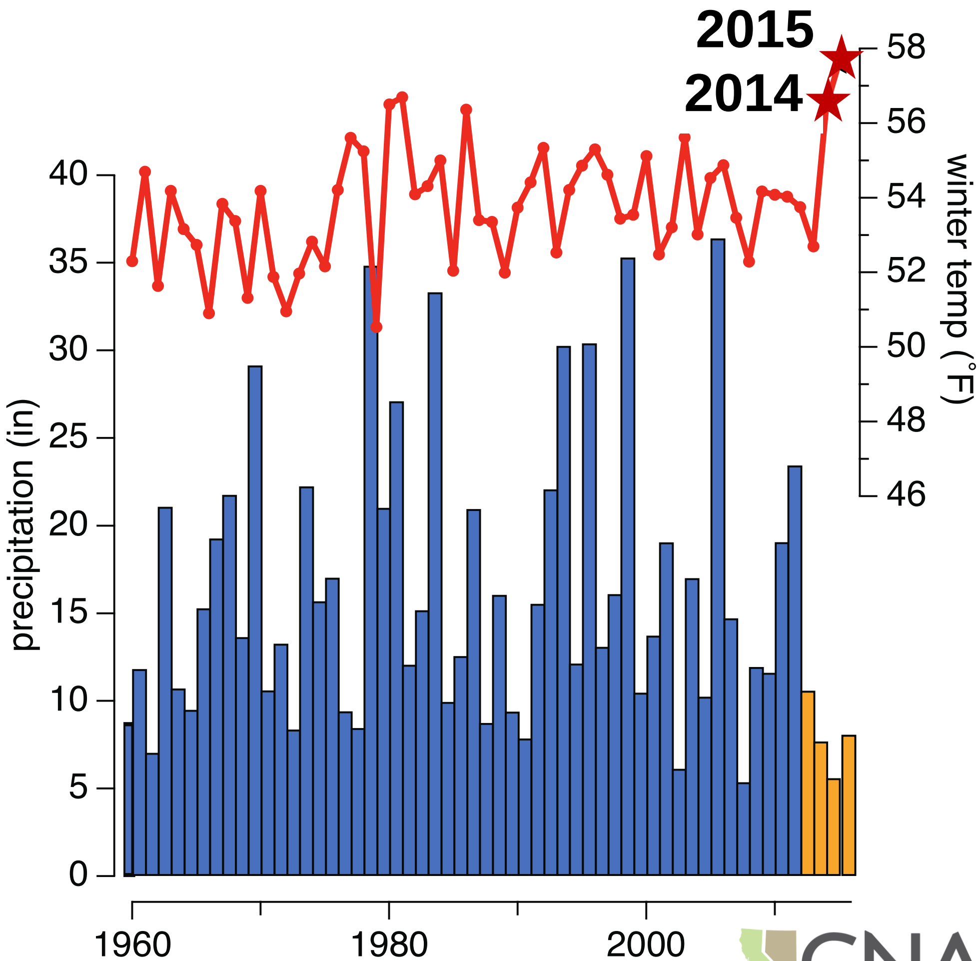
Know the climate and impacts – provide stakeholders with information that clarifies and extends what they already know

Be prepared for an evolving set of questions and expectations involving drought prediction

Outreach is critical but requires simplicity

Lesson #1: Know the climate & impacts – provide stakeholders with information that clarifies and extends what they already know

- Use historical observed variability to explain newly unfolding events, and when possible as an analogue for decision makers to understand future climate changes (e.g. the exceptionally warm dry years in 2014 and 2015)



Data from the CA Climate Tracker, WRCC
http://www.wrcc.dri.edu/monitor/cal-mon/

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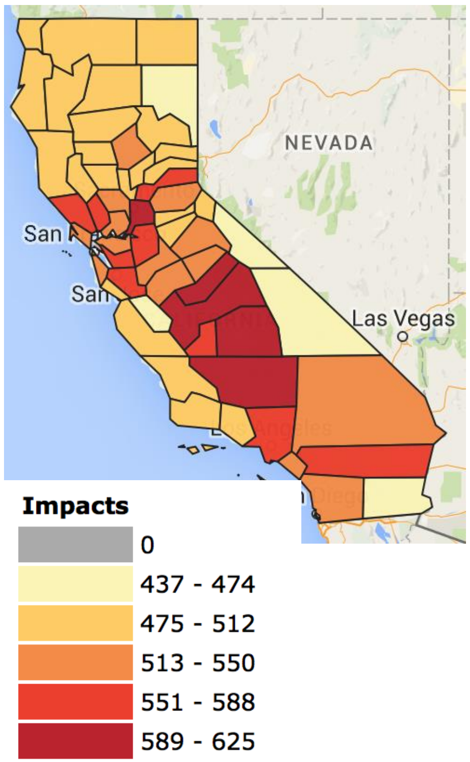
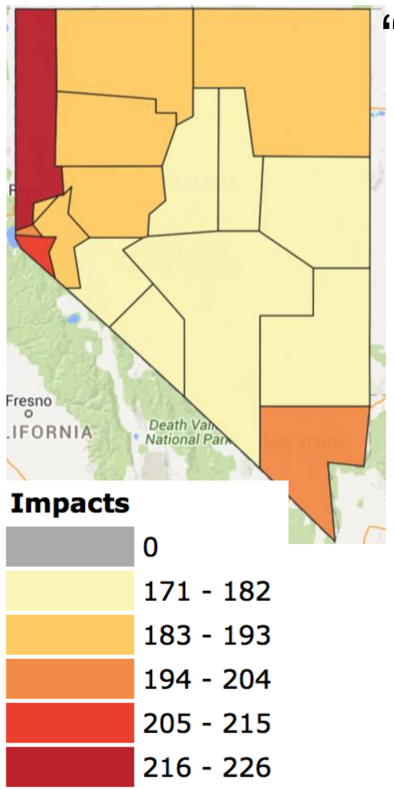
Lesson #1: Know the climate & impacts – provide stakeholders with information that clarifies and extends what they already know





"Drought is defined by its impacts!"
– K. Redmond

- Impacts vary enormously over the states and sector.

NDMC Drought Impact Reporter
October 1, 2011 – February 16, 2016
http://droughtreporter.unl.edu/map/

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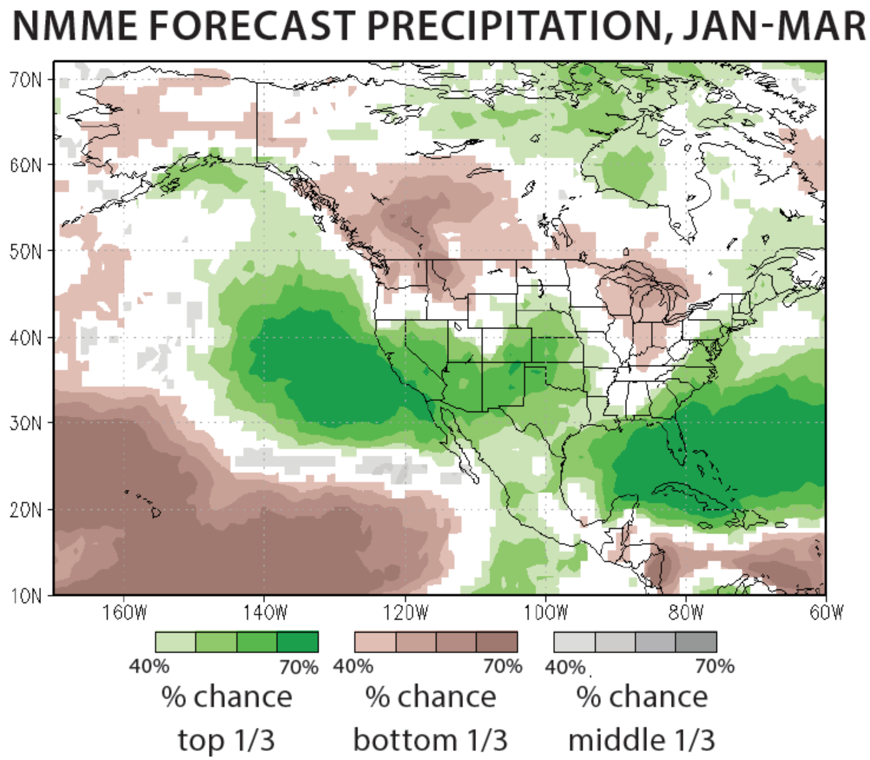
Lesson #2: Be prepared for an evolving set of questions and expectations involving drought prediction

- Be able to explain source of seasonal forecast skill and describe uncertainty
- Illustrate how drought has developed, persisted and eased in past cases



Experimental NMME forecast for precipitation for Jan-Mar from the NMME, showing chance of T/P by percentile. CNAP Research by S. Shukla.

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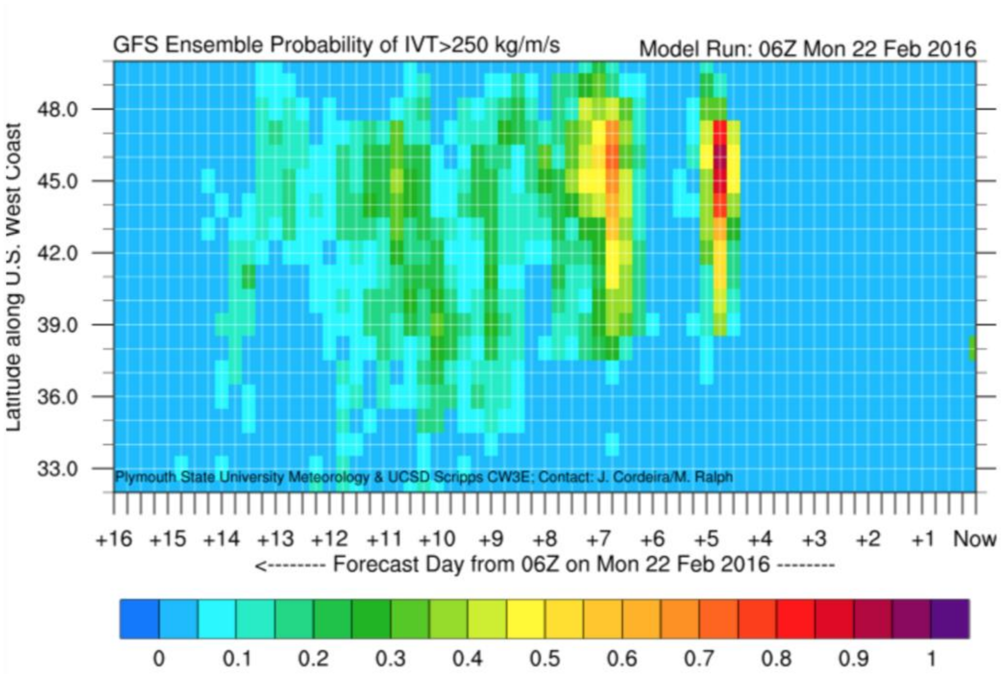
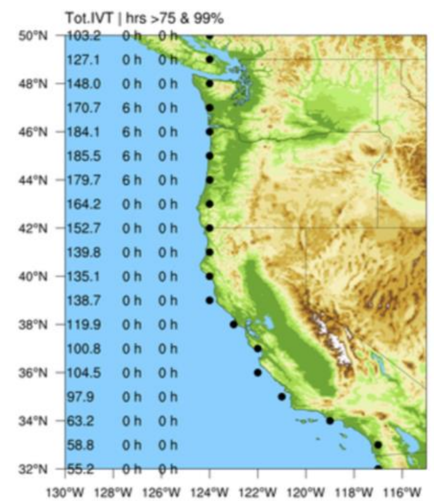
Lesson #2: Be prepared for an evolving set of questions and expectations involving drought prediction

- CA & NV's fluctuating yearly water supply is highly dependent on the occurrence (or lack of) a few large storms
- Short term forecasts improvements are critical





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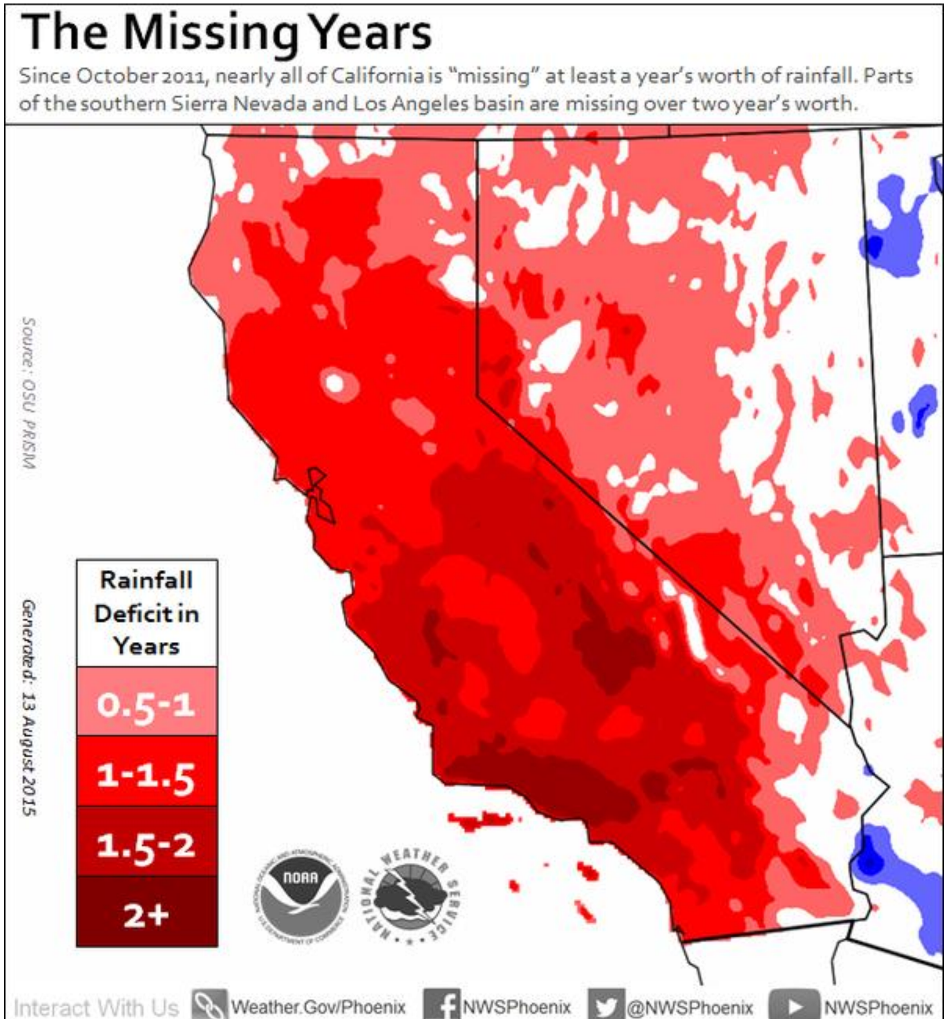
Courtesy of CW3E, http://cw3e.ucsd.edu

Lesson #2: Be prepared for an evolving set of questions and expectations involving drought prediction



How long will the drought continue?

Is one good year enough?

What will it take to "bust" the drought?

- New CNAP tools in development and testing

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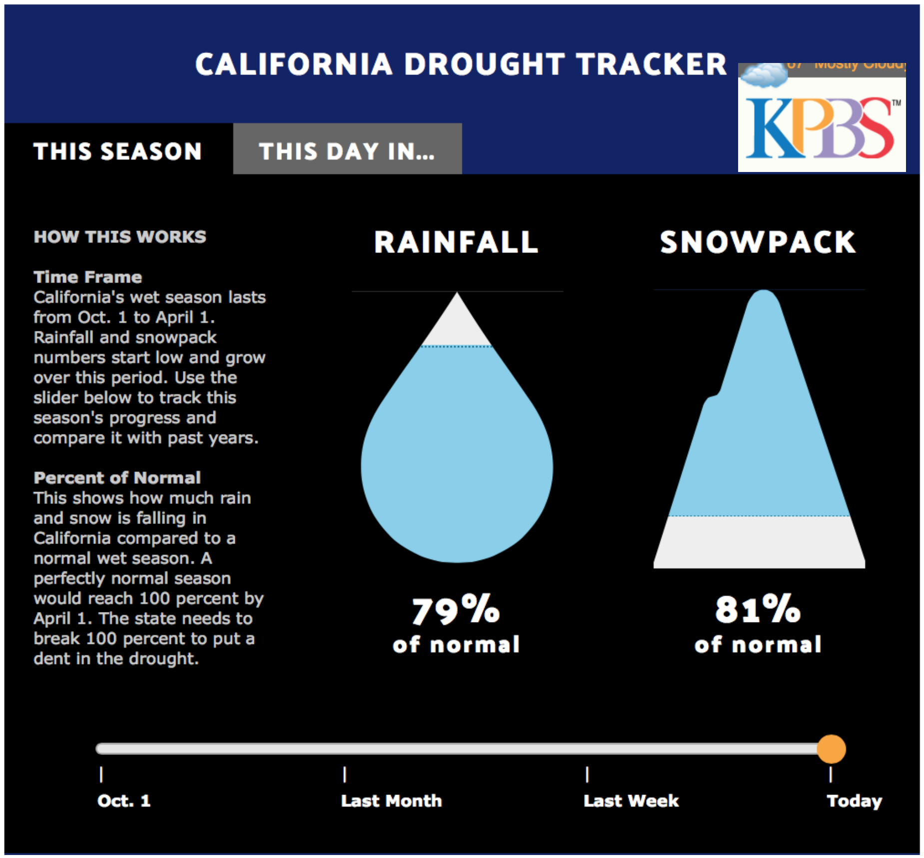
Lesson #3: Outreach is critical but requires simplicity



DATA SOURCES: Rainfall data comes from a weighted average of 96 weather stations throughout the state. Snowpack data represents the average of three different multi-station measures of the northern, central and southern Sierra snowpack. Scripps Institution of Oceanography researchers, through the California Nevada Applications Program RISA and the Center for Western Weather and Water Extremes, helped compile the data.

- In recent years, up-to-date information is highly sought by the public who seek local and regional picture of drought
- Media collaborators at Public Broadcasting have emphasized need for easily understood drought measures and simple graphics
- Ongoing linkages with responsible Media are invaluable in extending communication outreach

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CALIFORNIA PRECIPITATION

Seasonality of Precipitation

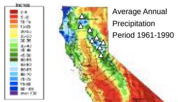
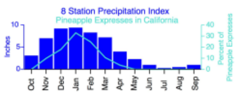


Figure 1. The locations of the 8 stations incorporated into the index is plotted on top of the average annual precipitation for CA (PRISM data set). The monthly distribution of the Northern Sierra 8-Station Index and Pineapple Express storms (strong atmospheric rivers) are graphed below.

Precipitation in California is highly variable year-to-year and understanding this variability is critical to water resource management and policy. California has a Mediterranean climate – cool, wet winters and warm, dry summers. This means that the bulk of California's precipitation falls in the cool season months from October through April. It is highly variable across the state with the southeast deserts receiving less than 5 inches in a year to the north coast which can get over 100 inches per year. One way to visualize the temporal distribution of California precipitation is using the Northern California 8-station precipitation index from the California Department of Water Resources. The index, which averages 50 inches per year, gives a sense of how much precipitation the Sacramento River watershed – a key area for the state's water supply - has received. A map of the location of the stations is shown in Figure 1 along with the average monthly distribution of precipitation. As can be seen in Figure 1, about half the annual precipitation total arrives in the three-month period from December through February and 90% of the annual precipitation falls between October 1 and April 30.



During this time period, winter storms come off the Pacific Ocean delivering rain and snow to California. Some of these storms include moisture from atmospheric rivers – narrow bands of high concentration water vapor that extend from the tropics – and deliver heavy precipitation to the state which can lead to flooding (Ralph et al., 2006; Fig. 2). On average 5-7 larger storms contribute most of the precipitation that falls during the wet months (Dettinger et al., 2011). When more storms arrive, conditions are wetter; when fewer storms arrive, conditions are drier.

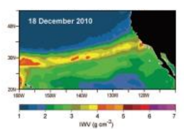


Figure 2. Image of an atmospheric river making landfall in California (Ralph and Dettinger, 2012)

Climate Change

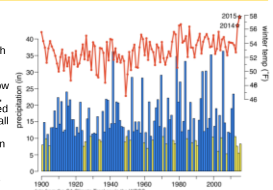
Research to date provides no clear signal of how precipitation may change in California as climate changes. Although precipitation changes are uncertain, climate models agree that California will become warmer. The increased temperatures will mean more of the precipitation will fall as rain instead of snow which will change the timing of river flows in the state. Efforts are underway to develop a metric to track the rain versus snow percentages

Ralph, F. M., et al., 2006, Geophys. Res. Lett., 33, L13801.
Ralph F. M. and Dettinger, M.D., 2012, Bull. Amer. Meteor. Soc., 93, 783
Dettinger, M. D., et al., 2011, Water, 3, 455-478.
Dettinger, M.D. and Cayan, D.R., 2014, San Francisco Estuary and Wat

May 2015

DROUGHT IN SOUTHERN CALIFORNIA

Four Years of Drought



California is in its fourth consecutive year of drought. The blue and yellow bars in the graph on the right show the total precipitation in the South Coast Region during each water year (October to September) since 1900. The yellow bars indicate the 30 driest years in the record, and the only time that four such years occurred in a row is from 2012-2015. Since 2013, rainfall accumulation in the South Coast region has been 21.5 inches, which is 30 inches less than the average accumulation for a three year period, and Southern California was already experiencing a deficit as we entered the 2013 water year.

The red line on the top shows the average winter (December, January and February) temperature for the region. The two warmest winters on record were 2014 and 2015. These record temperatures exacerbate the drought by increasing evaporation from soils and vegetation, thereby increasing irrigation demands. Drier and warmer conditions prolong and exacerbate seasonal wild fire risks. In mountain catchments, the warm temperatures also led to more precipitation falling as rain instead of snow, yielding by far the lowest snowpack amounts ever recorded, which directly impact Southern California's water supply (see back).

Year-to-Year Variability & Large Storms

California has a uniquely variable historic range of precipitation, and Southern California has the most variability of all (Dettinger et al. 2011). California's year-to-year variability derives primarily from the vagaries of its largest storms. In Southern California about 90% of year-to-year precipitation variability comes from year-to-year fluctuations in its wettest handfuls of days. This means that wet and dry years in California are opposite sides of the same coin. Drought in California occurs during years missing a few large storms and wet years occur when there are extra large storms (Dettinger and Cayan, 2014).

Is it Climate Change?

The persistent dryness and the unusual warmth during the current drought raise the question of whether climate change is playing a role. The recent lack of precipitation remains difficult to attribute directly to climate change. However, tree ring-reconstructions of precipitation and soil moisture in California going back 1200 years have indicated that the severity of the ongoing drought is highly unusual if temperature is also taken into account (Griffin and Anchukaitis, 2014). The study shows that California has experienced over 60 droughts lasting between 3-9 years in the last 1200 years, but the current drought, from 2012-2015, has been the most extreme when the high temperatures in Southern and Central California are factored in. Future projections of precipitation in California are uncertain, but all climate models predict significant warming in the next century. As in the current drought, warmer temperatures make the effects of drought more severe. Thus, although it is hard to distinguish climate change from natural climate variability, the current drought is an analogue of the kind of drought that we expect to become more common and even more severe in the future.

Griffin and Anchukaitis., 2014, Geophys. Res. Lett., 41(24).
Dettinger, M. D., et al., 2011, Water, 3, 455-478.
Dettinger, M.D. and Cayan, D.R., 2014, San Francisco Estuary and Watershed Science, 12(2).

The **CA State Climatologist** is supported by California Department of Water Resources to collaborate with NOAA programs to provide climate information and interpretation for CA.
CNAP, the California Nevada Applications Program, is a NOAA RISA team conducting applied climate research that is inspired by and useful to decision makers in the region.
NIDIS, National Integrated Drought Information System, works with federal, state, tribal and local partners to improve drought early warning, preparedness and response to impacts.
The **SWCSC**, Southwest Climate Science Center, sponsored by the U.S. Dept. of the Interior provides scientific information and tools to anticipate, monitor, and adapt to climate change.

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CALIFORNIA HEAT WAVES

JULY 2015

A New Type of Heat Wave

Heat waves in California and Nevada are traditionally dry and tolerable. The temperature warms up during the day and normally cools off greatly at night allowing plants and animals to recuperate and get ready for another day of scorching heat. However, this traditional type of heat wave, natural for our semi-arid Mediterranean climate, has increasingly tended to be more humid and more often accentuated at night since the 1980s (Figure 1). Humidity, that is water vapor in the air, absorbs infrared radiation emitted by the earth's surface hampering the ability of the surface to cool off. In short, humidity leads to higher night time temperatures. Humidity makes the difference between cool desert and sultry bayou nights. Increased humidity also makes extreme heat much more difficult for humans as it reduces our bodies' ability to cool off by evaporating water – sweating. Humid heat waves start off with higher temperatures in the morning and tend to reach higher temperatures during the day, lasting longer than their dry counterparts. The observed trend towards more humid, more intense and longer-lasting heat waves in California[1] has so far culminated in the July 2006 heat wave, an event of unprecedented impact on human health in the state (see box). Californian plants and animals are not acclimated to persistent humid heat, making them more likely to succumb.

Great heat waves are rare. Heat waves impacting California are caused by a specific weather pattern characterized by high atmospheric pressure in the Great Plains and low pressure off California's coast which together draw warm moist air from the south. Coastal waters west of Baja California are an important source for this humid air; these waters have become unusually warm in recent decades as part of a global warming pattern. This ocean warming has been partially responsible for the fact that the rare weather patterns associated with great California heat waves have tended to bring warmer, more humid air.

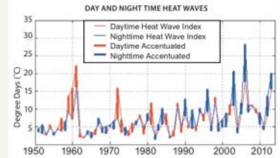

Figure 1. The graph shows heat wave activity since 1950. The red line is based on maximum temperatures and the blue line is based on minimum temperatures. Degree days are the sum of degrees that exceed the 95th percentile of daily temperatures during June, July and August. The bold parts of the graph indicate when the heat wave activity is accentuated in minimum or nighttime temperatures (blue) or during the day (red), predominantly humid or dry days respectively.

In California, occasional great heat waves punctuate an increasing trend in heat wave activity observed since around 1980 (Figure 1). These heat waves have changed from the traditional dry daytime-accentuated heat waves in the summers of 1959, '60, '61, '72, '81 to the humid nighttime-accentuated heat waves of 1990, '96, 2003, and '06. The trend towards nighttime-accentuated humid heat waves has continued in summers 2012 and '13, although we have not seen a heat wave of 2006 magnitude since.

2006 HEAT WAVE &HEALTH

The 2006 California heat wave killed more than 600 people[2], 147 directly by hyperthermia[3], and resulted in over 1,200 hospitalizations and 16,000 emergency-department visits[4,5]. Most of the deaths from hyperthermia occurred in inland counties, which were the hottest, while the highest morbidity (illness) was along the highly vulnerable coast[5] (discussed on back). The 2006 heat wave also had grave effects on ranching and agriculture, ecosystems and the energy sector. In severe drought years, like this one, a great heat wave could additionally exert significant water resources.

1. Gershunov et al., *Journal of Climate*, 2009.
2. Ostro et al., *Environmental Research*, 2009.
3. Trent, R. B. 2007: Review of July 2006 heat wave related fatalities in California. CA Dept. of Health Services Report.
ealth Perspectives, 2009.
pplied Meteorology and Climatology, 2014.
nate Change Center CEC-500-2009-014-D, 2009.
Geophysical Research Letters, 2012.

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EL NIÑO IN CALIFORNIA AND NEVADA

DECEMBER 2015

What is El Niño?

El Niño occurs when Pacific trade winds slacken, which weakens equatorial upwelling and warms the waters at and below the surface in the eastern half of the tropical Pacific (Figure 1). NOAA declares El Niño conditions when sea surface temperatures (SSTs) in the Niño 3.4 region, east of the International Date Line, are 0.5°C (~1°F) warmer than normal for 5 or more overlapping 3-month periods. Associated with these abnormally warm SSTs, the region of deep convection (thunderstorms and rainfall) shifts eastward to the central and eastern tropical Pacific, linking anomalous conditions near the ocean's surface to the atmosphere aloft. The unusual heating of the tropical atmosphere changes temperature, precipitation, and atmospheric circulations over global scales. A common pattern during El Niño is a more expansive Aleutian Low with a southward shifted North Pacific storm track into the western US, which modifies weather in California and Nevada.

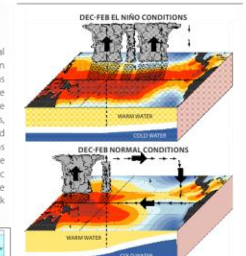


Figure 1. During El Niño conditions (top figure), the typically thin layer of warm surface water (shown in bottom figure) in the eastern equatorial Pacific thickens. Sea surface temperatures increase off the coast of South America and in the central Pacific along the equator. The warmer equatorial Pacific surface waters observed during El Niño result from the confluence of several events in the atmosphere and ocean. Image source: NOAA NWS

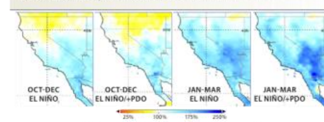
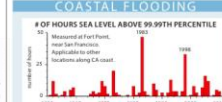


Figure 2. Composite precipitation % of normal for moderate/strong El Niño events: 1957-58, 1963-64, 1965-66, 1972-73, 1982-83, 1986-87, 1987-88, 1991-92, 1997-98, 2002-03, 2009-10; El Niño/+PDO events: 1982-83, 1986-87, 1987-88, 1991-92, 1997-98, 2002-03, 2009-10. Data source: Livneh

Past El Niño events in CA and NV

During El Niño, wintertime precipitation is often above normal across the southern third of CA and NV, but it has not been consistent (both wet and dry) in central and northern CA and NV. However, in past Very Strong El Niño events (Niño 3.4 SST anomalies >2.0° C), wetter conditions were more widespread, covering most of the two states. This fall (2015), the current El Niño is on par with the Very Strong 1982-83 and 1997-98 El Niño events-- thus there appears to be a higher likelihood of widespread above normal precipitation in CA and NV during winter 2015-16. Additionally, North Pacific SSTs are currently registering the positive phase of the Pacific Decadal Oscillation (PDO), as they were in 1982-83 and 1997-98, which can reinforce El Niño precipitation impacts in CA and NV-- thus the El Niño/+PDO composites shown in Figure 2 may serve as an analog for the current winter.

COASTAL FLOODING



During an El Niño event, water along the West coast is often warmer than normal and upwelling is supressed, creating higher than normal sea levels. Along the California coast, sea levels during Very Strong El Niño events, especially 1982-83, were extremely high. When heightened sea levels coincide with high tides and strong storms, coastal flooding can occur, as it did in California during the 1982-83 El Niño event.

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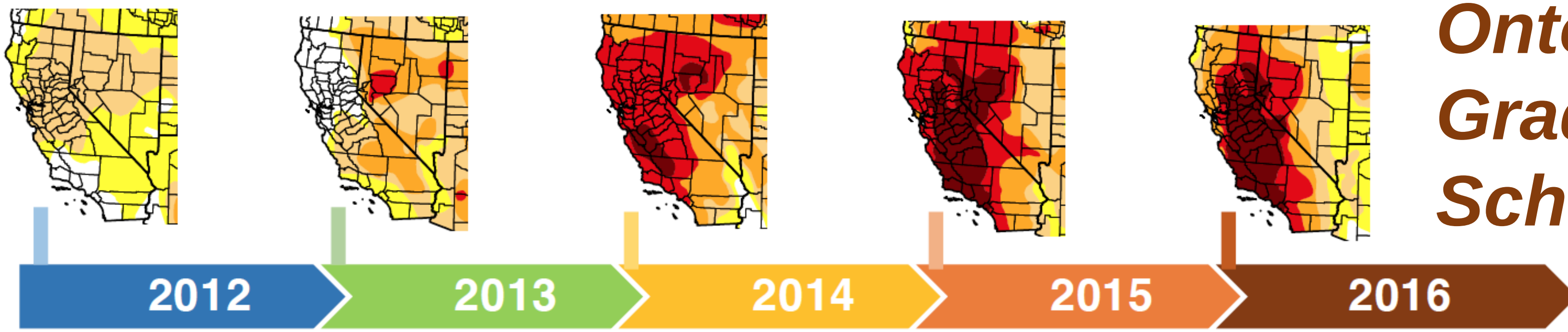

Onto Graduate School???

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